

# **Estimating coho salmon escapement and mark rates in the Elwha River in 2021 using multi-beam SONAR technology**



**Photo Credit: John McMillan**

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## Executive Summary

We used an ARIS 1800 multi-beam SONAR unit to monitor coho salmon escapement in the Mainstem, or East Channel (EC) of the Elwha River on a daily basis from August 23, 2021 through November 9, 2021. We analyzed 20-minutes of each hour long file and then adjusted these raw counts for expansion to hourly counts, species composition, observer error, and filling data gaps. This process yielded an adult coho (>500 mm) escapement estimate above the EC SONAR site of 5,900 fish, with a coefficient of variation of 3.1% (95% CI 5,535 –6,225). We also operated a DIDSON (LR) SONAR in the Hunt Road Channel (HRC) for four different periods ranging in length from two to five days and provide a low, medium, and high estimate of passage up that channel for the entire run of 130, 330 and 450 fish respectively. Taking the EC estimate and the medium estimate for the HRC yields a total escapement estimate of 6,200 coho to the Elwha River in 2021. Using the low and high ends of the 95% CI and adding the low and high estimates from the HRC, respectively, yielded upper and lower bounds of the total escapement of coho greater than 500 mm to the Elwha in 2021 of 5,660 and 6,780 fish. We used two different methods to estimate jack coho (<500 mm) escapement and they approximated 680 and 580 jack coho salmon.

Fifty percent of the coho salmon run passed the SONAR sites by October 7, five days later than 2020 and two weeks later than 2019. The first coho was captured in species composition sampling on August 23 and the last was captured on November 2. High water in November, including an extreme flood event on November 15, caused an end to the season approximately two weeks earlier than in 2019 and 2020. Species composition sampling produced 126 coho greater than 500 mm for mark rate tabulation with adipose clip only, CWT only, and both marks representing 95%, 2%, and 4% of marked fish, respectively. Additionally, 55% of all captured fish over 500 mm were not marked in any way and can be considered natural origin fish. The male: female ratio for adult coho from the net sampling was 1.4:1 (69:47). Subtracting the adult hatchery returns (438) from our adult total return estimate produces a total adult return to the river of 5,760 coho. Based on the net sampling sex ratio, approximately 2,300 of the in river spawners would be female. Hatchery returns showed almost an inverse male: female ratio of 0.76:1 (320:417) so the estimate of female in river spawners should be used with caution.

The major recommendation for future years is to move the Mainstem SONAR site upstream of the hatchery intake to avoid extreme milling during portions of the coho run. We also recommend performing some level of net sampling in the middle and upper river in future years to further evaluate the longitudinal variation in pHOS that was evident from sampling in 2020.

## Introduction

One of the most important pieces of information for salmon fisheries managers is an accurate count of adults returning to spawn in a river system, hereafter referred to as escapement. Multiple methods have been used to estimate escapements of adults, including aerial surveys, counting towers, weirs, redd surveys, mark recapture, and SONAR technology (reviewed by Cousens et al., 1982). Over the years, the technology and techniques involved has remained basically static for most of these methods except SONAR, whose technology and application to escapement estimation has rapidly evolved over the last few decades (Maxwell 2008).

Single beam SONAR systems have been used to enumerate fish migration in rivers since the early 1960's. Similar technology is still being used to measure escapement in a number of commercial fisheries in Alaska (Westerman and Willette 2003; Dunbar and Pfisterer 2004; Dunbar 2001, 2003; McKinley 2002), and Canada (Levy et al. 1991, Cronkite et al. 2006). More recently, SONAR technology has greatly improved counting accuracy by incorporating multiple high frequency beams, producing "movie" quality images while also providing detailed data on several other fish characteristics including direction of travel, range, length, and swimming speed (Belcher et al. 2001, 2002). The main unit in use for fisheries applications today is the **D**ual-frequency **I**Dentification **S**ONar (DIDSON) and its newer version, the **A**daptive **R**esolution **I**maging **S**onar (ARIS).

Several studies have compared sonar counts of adult salmon derived from DIDSON imaging systems to other enumeration methods such as weir passage (Holmes et al. 2006), visual counts (Enzenhofer et al. 1998), and mark-recapture (Cronkite et al. 2006, Holmes et al. 2006). These studies have shown that SONAR counts were more accurate (insignificant error calculations) when compared to more traditional methods. It is important to note; however, that almost all of the fisheries applications of SONAR are focused on large salmon runs that transpire over the course of only a few weeks, which requires large technical staffs and operating budgets (eg. Lilja et al. 2008, Enzenhofer et al. 2010).

SONAR has been used to enumerate winter-timed steelhead (*Oncorhynchus mykiss*) and summer/fall Chinook salmon (*O. tshawytscha*) in the Elwha River, Washington from late January/early February through late September since 2010 (Denton et al. 2010-2022). This is the third year the project has continued operations throughout the fall and into the winter in an attempt to enumerate coho salmon (*O. kisutch*), as well as document the mark rates of the returning adults.

Although not listed under the Endangered Species Act, coho salmon are a stock of interest to various stakeholders on the Elwha. Attempts at enumerating escapement with redd surveys have been ongoing since at least 2013 but due to high flows and low visibility during their spawn timing, these surveys have not been useful for estimating total basin escapement which has led to this current effort to improve enumeration. Prior to dam removal, Elwha coho were managed for hatchery production and returns were dominated by hatchery origin fish (HOR). Since dam removal, coho have recolonized the middle river and its tributaries and the lower portion of the upper river to at least Geyser Valley. Additionally, the stock is of regional concern for fisheries managers interested in assessing mark

selective fisheries in salt water and has therefore been the subject of a targeted mark program whereby all hatchery releases are marked by a combination of two different marks, an adipose clip and/or a CWT tag. Information on the relative proportions that these mark rates represented in the adult returns is critical to evaluating the effects of mark selective fisheries.

The objectives of this study were 1) to enumerate the number of non-jack (>500 mm) and jack (< 500 mm) coho salmon migrating passed the SONAR sites; 2) provide mark rate information on all captured coho; 3) provide run timing information; 4) incorporate and describe various sources of error in the estimate; 5) determine the proportion of coho and other species in the river during the course of the run; and 6) make recommendations on how to improve the project in future years.

## Methods

### *Data Collection*

Continually changing river conditions and two distinct stream channels (migratory pathways) in the lower Elwha River necessitated two separate SONAR installations to accurately detect coho passage in 2021 as the river splits into two significant channels (Fig. 1). The primary enumeration site was located in the Mainstem, or East Channel (EC) (formally referred to as the Old Mainstem) while a secondary site was located in the Hunt Road Channel (HRC). Both sites were located at approximately RKM 0.8. While current data does not exist on the proportion of flow down each channel, at flows above approximately 1,200 cfs, roughly 20% of the flow is transported down the HRC, with the remaining 80% traveling down the EC. At total river flows less than approximately 1,200 cfs, roughly 10% of the flow is transported down the HRC (Personal communication, Mike McHenry 2019). Two different SONAR units were used during the course of this study; a DIDSON LR (long range, 0.7/1.1 MHz, provided by NOAA Fisheries) and an ARIS 1800 (1.1/1.8 Mhz, provided by the National Park Service – Olympic National Park).

Site selection was based on four criteria: 1) almost all fish would pass the site; 2) the location was downstream of the majority of coho spawning habitat; 3) the river channel was sufficiently narrow to accommodate the effective range of the SONAR; and 4) fish movement was primarily directed upstream with little milling in the location of the SONAR. Depending on stream flow, the HRC site was between 15 and 20 m across and 1.8 meters deep in the thalweg, while the EC site was 22-32 meters wide and 2 meters deep in the thalweg.

Each SONAR was attached to a pole mount (Enzenhofer and Cronkite 2005) that was mounted on a reinforced aluminum step-ladder. The SONAR and ladder were positioned just under the surface of the water with a downward angle of approximately 4-6° (Fig. 2). The goal of this placement was to ensonify the bottom of the river across the entire width of the channel in addition to clearly identifying the far bank (see Enzenhofer et al. 2010 for details on aiming the beam).

The HRC site was connected to line power, which ensured a constant power supply. The EC site

was powered by a 24-volt, 400 amp hour battery bank that was continually charged by an array of solar panels (Fig 3).

Coho salmon passage was recorded at the EC site from August 23 through November 9 with two short recording gaps of two days (October 10, 11 and October 16, 17) and one longer gap of 12 days (October 20 through October 31) (Fig. 4a). These gaps were mostly due to high flows but also to power issues. Data was recorded on the HRC for four different multi-day periods, two in September, and one each in October and November (Fig. 4b). The gaps were a product of both low flows in that channel for extended periods of time and the limited scope of work of the project.

Because of the limited amount of data present for the HRC, the data analysis procedures presented below were only performed on the EC data. The procedure for estimating passage up the HRC is presented at the end of the data analysis section.

### **Species Composition**

We conducted ten tangle net surveys between August 23 and November 22, 2021 to capture live adult salmonids at eight different sites in the lower three kilometers of the river. We did this to differentiate species of salmonids over the course of the run and to determine the total duration of the coho run. Captured fish were measured for fork length and qualitatively categorized as “new” if they appeared to have entered the river within the previous 2 weeks, “holding” if they appeared to have been in the river for more than 2 weeks, or “spawned out” if they appeared to have initiated spawning or were already spawned out. The tangle-net was designed to snare fish from the jaw and not the gills in order to reduce encounter effects and limit sampling bias. The net was approximately 18 m long and 3 m deep with loosely hung 10 cm stretch mesh.

We also used the in-stream netting data to determine a minimum threshold for SONAR measured targets to be included in the final escapement estimation by comparing the lengths of coho and all other salmonids (Fig 5). Additionally, fish captured during species composition netting in conjunction with fish captured during additional sampling at supplemental upstream sites were used to determine mark rates of coho salmon.

### *Data Analysis*

#### **Post Processing**

All DIDSON data was processed using DIDSON proprietary software (V5.25.26). There were 24 hour long files for each day of operation. Twenty minutes of each hour of each file was reviewed. Raw data was transformed in a four step process that enabled empty periods of time to be efficiently reviewed, while still highlighting fish passage events for closer inspection. Files were background subtracted, using the default parameters, to remove rocks and make it easier to discern moving objects, such as migrating fish. Subsequently, each file was transformed into an echogram using the default parameters, with the exception that all 96 beams were included rather than only the center beam. This dramatically increases the probability that any fish entering the ensonified area was detected in the echogram.

An echogram is a graph of the data with distance from the SONAR head on the y-axis and time on the x-axis. If no targets are present, the echogram is blank. If a fish swims through the ensonified area, the echogram has a series of targets connected along the x-axis, whose overall length correlates with the length of time it took the fish to pass through the ensonified area. The string of targets along the x-axis may trend up or down along the y-axis if the fish was swimming diagonally away or towards the sonar head during its passage. To count fish passage events, target echograms were simultaneously reviewed along with the raw video file. This enabled the reviewer to quickly scan through an echogram until a target pattern that could potentially represent a fish was encountered. The raw video imagery was then reviewed to ensure identified targets were indeed fish.

The procedure for processing ARIS data was the same (background subtraction, echogram formation, manual review of likely targets), except ARIS data is processed with its own software, ARISFish (v.1.5). After determining that a pattern on the echogram was indeed a fish, we noted several variables, including the date, time, direction (upstream or downstream), distance from SONAR head, and length (mm). Length was measured in centimeters using software specific procedures.

### **Escapement Estimation and Uncertainty Tabulation**

Basic fish passage is tabulated by simply subtracting downstream passage events from upstream passage events (Xie et al. 2005):

$$N = U - D$$

Where N is the net upstream movement of fish for a given period of time, U is the sum of upstream fish for that time period and D is the sum of downstream moving fish for that time period.

In order to sum the upstream and downstream passage events for each twenty minute file, we first had to determine which passage events to include in our analysis, namely the minimum length threshold. A length frequency histogram of the in-stream netting data revealed that coho were between 400 mm and 770 mm, with a break at roughly 500 mm that indicated a size difference between jack and non-jack coho (Fig. 5). Based on this data, only SONAR targets recorded as 500 mm or greater were included in the final escapement analysis. We also ran the model using only SONAR targets that measured smaller than 500 mm in an effort to produce a jack escapement estimate.

Raw targets meeting the above criteria were then aggregated into six-hour chunks, four per day. Each six hour chunk was then put through a four step adjustment simulation to determine the final escapement. This simulation used collected data to correct raw counts for the three major adjustments that make up the total escapement estimate: 1) expanding the 20 minute counts to represent full hour passage; 2) down weighting the expanded counts to reflect the proportion of SONAR targets that were coho; 3) adjusting the expanded coho counts to account for observer error; and 4) filling in any passage data for gaps in the expanded, corrected, coho data.

We used a simulation based approach and replicated this simulation procedure a large number of times (10,000). We initialized the values in each cell (328 rows, representing each of the 6-hour chunks and 10,000 columns, representing the iterations) to the net passage based on the raw counts from the files. During each of the four steps in the adjustment procedure described below, we were able to generate updated estimates of escapement, and at varying temporal scales (6-hour

estimates, daily estimates, and annual estimates). To determine the coefficient of variation for the final escapement, the standard deviation of all 10,000 estimates was divided by the mean of all 10,000 estimates. To generate CV estimates for each of the four individual adjustment procedures, we also applied each step of the procedure individually to the raw six-hour chunk counts from each channel.

### *20 Minute Count Expansion*

Although counting 20 minutes of each hour is on the upper end of recommended sub-sampling regimes (Lilja et al. 2008), it requires treating two thirds of the total passage data as unknown. In order to expand our 20 minute counts and encompass the uncertainty inherent in the process we counted the full 60 minutes of 10 six hour chunks for the EC (Fig 6). We regressed these 60 minute counts against those predicted from the first 20-minutes of the same six hour chunks to create a vector of residuals. Each raw 20 minute count was then adjusted by multiplying by 3 and adding a randomly sampled value from the residual vector. The CV for escapement for this step was calculated by summing all 6-hour chunks for each iteration, yielding 10,000 estimates. Then, the standard deviation of all 10,000 estimates was divided by the mean of all 10,000 estimates.

### *Species Composition*

Calculation of the 2021 coho salmon escapement only included SONAR targets recorded from August 23, the date of first coho capture, through November 2. A final sampling event occurred on November 22 that did not capture any fish.

In-river netting also provided the necessary data to adjust the raw counts to reflect just the number of coho moving past the SONAR sites (Table 1). Because of the low numbers of fish caught during some of the sampling events, we summed fish between adjacent events to arrive at daily totals of “all fish” versus coho caught. For the EC, we simulated the proportion of coho for a given iteration and day as:

$$p_{i,j,k} = \text{Binomial} \left( \frac{N_{i,j,k}^{coho}}{N_{i,j,k}^{total}}, N_{i,j,k}^{total} \right) / N_{i,j,k}^{total}$$

where  $i$  represents the iteration (1 – 10,000),  $j$  indexes the 6-hour chunk (1 – 328) and  $k$  indexes the channel. The total number of fish,  $N_{i,j,k}^{total}$ , and total number of coho,  $N_{i,j,k}^{coho}$ , were available on a daily basis, so the four six-hour chunks from each day were assumed to have the same species composition.

We then adjusted each of the raw counts for the proportion that were coho as a random draw from a Binomial distribution:

$$X_{i,j,k}^{coho} \sim \text{Binomial}(p_{i,j,k}, X_{i,j,k}^{total})$$

where X is the number of coho and total number of fish for each six-hour chunk.

The CV for escapement for this step was calculated by performing the correction directly on the net passage data. Then the counts of all 6-hour chunks were summed for each iteration, yielding 10,000 estimates. Finally, the standard deviation of all 10,000 estimates was divided by the mean of all 10,000 estimates.

### *Observer Error*

We quantified observation error by comparing counts for 14 six hour chunks between the primary technician and a more experienced, “expert” counter. Six hour total passage counts by the expert counter were considered to be a measure of “actual” passage and were compared to the technicians “predicted” counts (Fig. 7). A trend line was fit to the data with an intercept of 0 and then a vector of observer error residuals was generated. Each cell of the coho matrix was then adjusted by multiplying it by the coefficient from the regression trend line and adding a random residual. The CV for escapement for this step was calculated by performing the correction directly on the net passage data as opposed to the species composition adjusted data used by the simulation. Then the counts of each 6-hour chunk were summed for each iteration, yielding 10,000 estimates. Finally, the standard deviation of all 10,000 estimates was divided by the mean of all 10,000 estimates.

An additional, simplified method was used to deal with milling at the Mainstem site for the first seven days of October because it was impossible to get an “actual” measure of passage during this time period. Two reviewers counted the entire seven day period and their counts for each six hour chunk were averaged to estimate passage during this time period. No CV was associated with this procedure but the passage data from this seven day period was adjusted with the above described observer error procedure.

### *Filling Data Gaps*

A number of different approaches could be used to fill in missing counts, including borrowing data from the neighboring channel or assuming return timing to follow some distribution (normal, double half-normal, etc). We used a generalized additive modeling (GAM) approach to fill in missing values, because this approach also allowed us to include uncertainty estimates (gam in the ‘mgcv’ package in R). We fit a smoothing spline over time (days), which allowed both a flexible shape of return timing, and uncertainty to increase as the spline became further away from data. For example, if a 5 day data gap exists, the uncertainty is highest on the mid-point (day 3) of the gap, and the uncertainty associated with passage during the gap would increase as the length of the gap increases. For each iteration of the simulation, we first fit the GAM to fill in the data gaps, then for each six hour chunk generated random values (using the mean and corresponding standard error from the GAM). Because our approach does not include autocorrelation in missing values, but assumes each six hour chunk to be independent, it represents upper bounds of uncertainty estimates.

### *Estimating Passage up the HRC*

Due to the limited amount of recorded data on the HRC, a much more simplistic approach was taken to estimate passage up that channel. We were not able to report confidence intervals around an estimate but instead offer three different methods for calculating an estimate that can be viewed as a low, medium, and high approach. Fish passage was measured up both channels at a range of flows (700 – 2,600 cfs). The percentage of fish moving up the HRC on a daily basis as compared to the total passage up both channels ranged from 0% to 30%. Higher proportions of passage being related to higher flows with little to no passage recorded up the HRC at flows below 1,500 cfs and most passage associated with flows over 2,000 cfs. Therefore the three passage estimates for the HRC were estimated by varying both the minimum flow threshold for passage to occur up the HRC and the proportion of fish that passed when flows were above that threshold. The low passage estimate predicted that 15% of the fish passed up the HRC at flows above 2,000 cfs. The medium passage estimate predicted that 20% of the fish passed up the HRC at flows above 1,500 cfs. The high passage estimate predicted that 30% of the fish passed up the HRC at flows above 1,500 cfs

### *Estimating the number of jack coho salmon (<500 mm)*

We used two methods for estimating the total number of jack coho (<500 mm) to the Elwha in 2021. First, we simply took the total adult escapement estimate of 6,200 and multiplied it by the proportion of jack (14) to adult (126) coho captured in our species composition sampling or 11%. For the second method, the simulation model was run using only SONAR targets and species composition netting samples measuring less than 500 mm. The second method only estimated the number of jack coho that traveled up the EC, so was increased by the same proportion of adults that moved up the HRC as compared to the number of adults that moved up the EC from the middle estimation method (5%).

## **Results**

Between August 9 and November 9, 2021 there were a total of 1,512 hours (63 days) recorded on the EC and 384 hours (16 days) recorded on HRC. The EC was monitored for 1,512 hours out of a total of 1,896 hours, or 80% of the total possible hours. During this time period 3,093 fish passage events were recorded and analyzed. The best estimate for coho (> 500 mm) passage up the EC of the Elwha River in 2021 was 5,900 fish with a coefficient of variation (CV) of 3.1% (95% CI 5,535 – 6,225) (Fig. 9, Table 2). The three estimates of coho (>500 mm) passage up the HRC were 130 fish, 300 fish, and 450 fish (Fig. 10). Using the middle estimate of passage up the HRC in conjunction with the estimate up the EC, we estimated that total adult coho escapement to the Elwha River in 2021 was 6,200 fish. Using the low and high ends of the 95% CI and adding the low and high estimates from the HRC, respectively, yielded upper and lower bounds of the total escapement of coho greater than 500 mm to the Elwha in 2021 of 5,660 and 6,780 fish, respectively. We calculated four sources of uncertainty for the estimate of passage up the EC, in decreasing order they are: (1) error in the gap filling procedure (4.1%), (2) the uncertainty associated with adjusting for observer error (2.1%), (3)

expanding 20 minute counts to full hour counts (2.4%) and (4) adjusting for species composition (1.3%) (Table 2).

The two jack estimates were similar at 680 for the simple jack:adult proportion method and 580 for the model based estimate.

The SONAR data in combination with in-stream species composition netting provided detailed information on run timing. We captured the first coho salmon on August 23 and 25%, 50%, and 75% of the run had passed the EC SONAR site by September 30, October 7, and October 19, respectively. Daily coho passage was also plotted against flow (Fig. 11). The run appeared to begin in earnest during the last week of September when the hydrograph initially increased after summer low flow.

In stream netting also provided 140 total coho for mark rate tabulation, of which 126 were adults. Of the 140 total coho, 59 fish (92% of marked fish) were ad-clipped only, 1 fish (1% of marked fish) was CWT marked only, and 4 fish (6% of all marked fish) were marked with both methods. An additional 76 fish (53% of the total captured) were not marked in any manner (Table 3a). Of the 126 adult coho assessed for mark rate, 54 (95% of marked fish) were ad-clipped only, 1 fish (2%) was CWT marked only, and 2 (3%) were marked with both methods. An additional 69 fish (55% of the total adults sampled) were not marked in any manner (Table 3b).

Subtracting the non-jack hatchery return of 438 (737 returned but 289 were subsequently outplanted upstream) fish from our non-jack estimate of 6,200 would produce an estimate of approximately 5,762 non-jack coho spawning in the river. In stream netting revealed a non-jack male to female ratio of 69:47 or 1.4:1. This would equate to a return of approximately 2,305 females to the river (Table 4).

## Discussion

We were successful at estimating coho escapement to the Elwha River for the third year in a row. We believe our escapement estimate of 6,200 coho salmon is robust for several reasons. Most importantly we recorded data from the main passage channel (EC) for what was likely the majority of the coho run. Net sampling occurred for weeks prior to the first coho being sampled and net sampling towards the end of the run showed declining catches, particularly near the mouth of the river. It is important to note that the last day of recording (November 9) was two weeks earlier than the previous two years of the project due to an extremely high flow event (~25,000 cfs) on November 15 and that coho likely migrated passed the SONAR sites after November 9. A final net sampling event occurred on November 22 and no fish were captured. Only 2.5% of the run passed the SONARs after November 9 in the previous two years of the project, so few coho likely went uncounted after November 9. We were also able to produce coefficients of variation for the four measured sources of uncertainty in our estimate. In decreasing order these sources were, (1) error in the gap filling procedure (4.1%), (2) the uncertainty associated with adjusting for observer error (2.1%), (3) expanding 20 minute counts to full hour counts (2.4%) and (4) adjusting for species composition (1.3%) (Table 2).

The highest source of uncertainty came from the gap filling procedure (4.1%). The CV associated with this procedure in 2021 was similar to last year and higher than the Chinook or steelhead project. This is almost entirely due to the highly variable hydrograph during this year's coho run which

necessitated removing the equipment during three different high flow events, one of which was 12 days long. Measured passage on either side of the 12 day gap was relatively variable with an average of ~125 fish passing upstream for the few days before it but only ~25 fish moving upstream passed it during the few days after the gap. This variation in passage on either side of a data gap makes it difficult for the model to predict passage during the gap. As mentioned previously, the SONAR was removed for the season approximately two weeks earlier than 2020 and three weeks earlier than in 2019. Passage during this “gap” at the end of the season was not estimated, although was likely very low. In 2019 and 2020, only 1.6% and 2.6% of the run passed the SONARs after November 9, respectively. This would equate to approximately 125 fish passing the SONAR after the end of operations on November 9 in 2021. A final species composition sampling event occurred on November 22 and captured no fish, providing further evidence that active entry of any significant number of coho had likely ended. However, 93 coho were processed at the LEKT hatchery during the last week of November and the first week of December in 2021, indicating some level of coho entry in late November. These fish are not enumerated as they enter the facility, only when they are spawned, so the actual entry time of them was earlier but likely only by a week. They also would have been holding in the river for an unknown amount of time before entering the hatchery facility.

It is important to note that the measured uncertainty only applies to the data gaps from the EC channel. The three estimates provided for passage up the HRC were simply three different scenarios encompassing the likely range of passage up that channel (130-450) but not enough data was collected from that channel to provide an estimate of the uncertainty surrounding those estimates. Widely variable flows (700 cfs – 4,000 cfs) affected the proportion of fish travelling up the HRC from 0% to 30%. The relatively limited variability in the proportion of fish migrating up the EC and our ability to accurately detect the minimum flow required for fish to pass up that channel gives us confidence in the lower and upper bounds of our estimate of passage up that channel. The range between our high and low passage estimates, 320 fish, only amounts to 5% of our total escapement estimate, so any additional error in passage up that channel would likely have little effect on our total estimate.

The second highest source of uncertainty was due to expanding 20 minute counts to full hour counts (2.4%). This is expected to be low as there is no reason why passage during the first 20 minutes of an hour should be any different than passage during the following 40 minutes, especially when averaged out over more than 2,000 hours.

The third highest source of measured uncertainty came from the adjustment for observer error. The measured CV (2.1%) of this adjustment was relatively low and similar to most other years and species of this project but it did not include any uncertainty for the seven day period from October 1 to October 7 where the average of two reviewer’s counts was used to estimate passage. As mentioned in previous coho reports, the EC SONAR site is located approximately 200 meters downstream of the LEKT hatchery facility which releases coho salmon that then home back to the facility as adults. This leads to a situation where hundreds of coho salmon hold in the reach where the SONAR is located, producing a milling phenomenon that makes accurately counting fish more difficult as they do not always consistently move upstream but rather swim back and forth multiple times before eventually moving upstream. High concentrations of fish and milling behavior in the SONAR reach is a problem the Chinook project routinely overcomes by simply moving the SONAR to the top of the riffle at the downstream end of the reach where fast moving water generally forces fish to move quickly upstream and out of the ensonified area. This location necessitates putting the SONAR in a very vulnerable position to increased

flows and can only be done when flows are reliably low. We were able to record the majority of the 2021 coho season from this shallower, faster moving location, but the large number of fish this year made the milling issue particularly onerous during the first week of October. This was likely due to the fact that approximately 1,000 more total fish returned in 2021 as compared to 2020 and almost all of them migrated up the Mainstem. As previously mentioned, to estimate passage during this seven day period, two reviewers counted the entire period and their aggregate counts for each six hour chunk were averaged. One reviewer counted 550 targets during this time period and the other counted 450, so 500 was used for the total passage during this time period. After adjusting for subsampling, observer error, and species composition, a range of 1,350 to 1,650 coho and an average of 1,500 coho passed the EC SONAR site during the first week of October. Any passage estimate within the range of the two reviewers is also plausible. See the recommendations section for suggestions on dealing with the milling issue.

The smallest source of uncertainty was associated with adjusting raw passage totals to reflect just coho passage (1.3%). This CV was low mainly because during the bulk of coho entry, late September through mid-October, coho made up the vast majority of our species composition samples. While there were still Chinook in the vicinity of the SONAR sites throughout September most of them were in spawning condition and were eliminated from the model input data. Over 2,000 pink salmon were estimated to have entered the Elwha this year but their run timing only slightly overlaps with coho and they are generally too small to be included in the species composition correction. Finally, only five chum were captured during the coho season and three of these were summer chum captured in September, one of which was spawned out. Although the project is not tasked with estimating chum salmon, the number of fall chum captured in 2021 (two) is by far the lowest the project has encountered and is cause for concern.

The two methods for estimating jack salmon escapement produced similar estimates of fish that were less than 500 mm, 680 for the simple jack:adult ratio method and 580 for the model based estimate. Both methods have likely bias and error associated with them that cannot be accurately quantified. For the jack:adult ratio method, it is likely that some portion of the smaller jack coho salmon simply slip through the net and are therefore underrepresented in our catch samples thereby biasing the jack estimate low. For the model based estimate the potential for review technicians to undercount smaller fish would also lead to an undercount of jack coho from this method. It is interesting to note that 461 jack coho returned to the LEKT hatchery in 2021. This represents 68% of the jack:adult ratio method and 79% of the model based estimate. This would represent a much higher return rate to the hatchery facility for jacks than was observed for the adult population (12%, 737/6,200). Due to the unmeasured uncertainty associated with the jack coho estimate it should be used with caution.

Redd surveys conducted on some middle and upper river tributaries during the 2021 coho season along with returns to the LEKT hatchery may be useful to compare to our escapement estimate. Olympic National Park staff counted a total of 179 redds in tributaries in the middle and upper river, the same as they counted in 2020 and more than the 163 they counted in 2019. The high flow events throughout November that ended the SONAR season prematurely also impacted the ability to survey redds in the middle and upper river. It is likely that several more undocumented redds were constructed as compared to the two previous years (H. Connor, Olympic National Park, pers. comm.). Surveys on Indian Creek and Little River, though limited by high water, did suggest an increase in coho spawning as compared to 2019 and 2020 with a total of 79 and 33 redds observed in Indian Creek and Little River,

respectively, the highest amount in either stream since dam removal. It should be noted that a total of 157 adult coho were transported from the LEKT hatchery to Indian creek on three different dates and likely created some of the observed redds, although only 11 of these floy tagged fish were subsequently resighted. Finally, 737 adult coho returned to the LEKT hatchery in 2021 an increase from 383 in 2020.

Fifty-four percent of our samples from the species composition netting were natural origin returns (NOR)(76/140)(Table 3a). When only considering coho over 500 mm, 55% were NOR (69/126) (Table 3b). This would represent a return of approximately 3,400 NOR adult coho. In previous years, using all fish to calculate pHOS would bias the return towards hatchery fish because the NOR proportion in the net sampling is biased low due to the proximity of several capture sites to the LEKT hatchery. Mark rates near the hatchery have been shown to be biased towards hatchery origin returns (HOR) fish in steelhead on the Elwha (Peters et al. 2020). In 2021 however, mark rates were very similar regardless of how they were grouped, with samples near the hatchery being 47% HOR (7/15), the sites below the channel split being 47% HOR (53/112) and the entire lower river being 46% HOR (64/140). Unfortunately no coho were sampled in the middle or upper river in 2021 and therefore larger scale longitudinal variation in pHOS could not be examined. There was a slight trend in temporal variability of pHOS with fewer hatchery fish sampled as the run progressed. Coho captured in September, October and November had pHOS proportions of 51% (32/63), 48% (31/65), and 8% (1/12) respectively.

Our timing information can be compared to the entry timing data from 2019 and 2020. The fifty percent entry date (October 7) was five days later than in 2020 (October 2) and two weeks later than 2019 (September 25). The 75% passage date (October 19) was almost a week earlier than 2020 (October 25) but a little more than a week later than in 2019 (October 10), generally indicating a run that is more protracted as the total run size and the proportion of natural origin returns increases. In all three years of the project, coho passage had evidently stopped by late November (although that was difficult to ascertain in 2021), much earlier than other stream in Western Juan de Fuca. Pess et. al. (2020) found that the average return date for coho salmon from NOR populations in three Western Juan de Fuca stream was during the month of November, a month later than our 50% return date. Even though we stopped operations earlier this year (November 9) the number of fish we likely missed (~125) was not significant to the overall run size. However, as the run rebuilds it will likely continue later in to the year.

Our adult female return to river estimate can be useful for estimating potential egg deposition and forecasting subsequent juvenile outmigration. It is obviously highly dependent on the male:female ratio from our net sampling. This ratio was heavily biased towards males this year (60% male (69/116) adults only, not all samples were sexed). It is interesting to note that the male:female ratio from the hatchery collections were almost inverse from our field collections (43% male, 320/417, adults only). If the hatchery sex ratio was used to calculate female return to the river there would be an estimated 3,860 females spawned in the river instead of the 2,300 estimated when using the net sampling sex ratio.

## **Recommendations**

Our major recommendation resulting from the 2021 coho season is to move the Mainstem SONAR site upstream of the hatchery intake. The flood at the end of the 2021 season significantly changed the existing SONAR site to the point where it is no longer tenable. Moving the SONAR site upstream of the hatchery will also presumably help ameliorate the milling issue caused by fish staging below the hatchery. There is a suitable site ~100 meters upstream of the hatchery intake that is being investigated.

We also recommend undertaking some level of net sampling in the middle river in future years to evaluate longitudinal differences in pHOS. This sampling revealed significant variation in 2020, with middle and upper river sites exhibiting lower pHOS values than the lower river.

We are pleased to report that the recommendation from the 2020 season of increased monitoring of the HRC along with the determination of minimum flow that allows passage up that channel was accomplished. Estimating coho passage up the HRC in 2021 introduced limited error into our overall escapement estimate.

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Table 1. Total number of “new” and “holding” coho and other salmonids by date at 6 sites during in-river netting operations in the lower 3KM of the Elwha River in 2021.

| <b>Date</b> | <b>Coho</b> | <b>Chinook</b> | <b>Pink</b> | <b>Chum</b> | <b>% Coho</b> |
|-------------|-------------|----------------|-------------|-------------|---------------|
| 8/23/2021   | 1           | 11             | 3           | 0           | 7%            |
| 9/7/2021    | 3           | 6              | 12          | 1           | 14%           |
| 9/14/2021   | 23          | 7              | 14          | 0           | 52%           |
| 9/20/2021   | 17          | 1              | 3           | 1           | 77%           |
| 9/27/2021   | 9           | 0              | 0           | 0           | 100%          |
| 10/4/2021   | 17          | 0              | 0           | 0           | 100%          |
| 10/12/2021  | 24          | 0              | 0           | 1           | 96%           |
| 10/18/2021  | 22          | 0              | 0           | 0           | 100%          |
| 11/2/2021   | 12          | 0              | 0           | 1           | 92%           |
| 11/22/2021  | 0           | 0              | 0           | 0           | NA            |

Table 2. Individual coefficients of variation for each adjustment procedure. The overall CV reflects the uncertainty incorporating all four sources of uncertainty and the individual CV estimates represent the uncertainty correction applied to the raw data to reflect the CV for each individual step.

| <b>Source of Uncertainty</b> | <b>OM (Total)</b> |
|------------------------------|-------------------|
| Expansion                    | 2.4%              |
| Species Composition          | 1.3%              |
| Observer Error               | 2.1%              |
| Gap Fill                     | 4.1%              |
| Overall                      | 3.1%              |

Table 3a. Mark rates for all coho captured in the lower 5 KM of the Elwha River between August 23 and November 2, 2021.

| <b>Mark</b>                      | <b>Ad Clip Only</b> | <b>CWT Only</b> | <b>Both</b> | <b>Neither</b> | <b>Total</b> |
|----------------------------------|---------------------|-----------------|-------------|----------------|--------------|
| <b>Raw Number</b>                | 59                  | 1               | 4           | 76             | <b>140</b>   |
| <b>Percentage of Marked Fish</b> | 92%                 | 2%              | 6%          |                |              |
| <b>Percentage of Total</b>       | 42%                 | 1%              | 3%          | 54%            |              |

Table 3b. Mark rates for coho greater than 500 mm captured in the lower 5 KM of the Elwha River between August 23 and November 2, 2021.

| <b>Mark</b>                      | <b>Ad Clip Only</b> | <b>CWT Only</b> | <b>Both</b> | <b>Neither</b> | <b>Total</b> |
|----------------------------------|---------------------|-----------------|-------------|----------------|--------------|
| <b>Raw Number</b>                | 54                  | 1               | 2           | 69             | <b>126</b>   |
| <b>Percentage of Marked Fish</b> | 95%                 | 2%              | 4%          |                |              |
| <b>Percentage of Total</b>       | 43%                 | 1%              | 2%          | 55%            |              |

Table 4. Three different estimates of coho returns to the Elwha River in 2021, all of which include passage up both channels. The first estimate is for coho greater than 500 mm. The second number subtracts out the non-jack hatchery returns (438). The final estimate applies the male:female ratio from the net sampling to the second estimate. See discussion for info on using the male:female ratio from the hatchery collections to calculate the third estimate.

## Estimate

|                                              |              |
|----------------------------------------------|--------------|
| <b>Total Non-Jack return</b>                 | <b>6,200</b> |
| <b>Total Non-Jack Return to River</b>        | <b>5,762</b> |
| <b>Total Non-Jack Female Return to River</b> | <b>2,305</b> |



Figure 1. Map of the lower Elwha. Former Elwha dam site is located at the bottom of the figure, with the Strait of Juan de Fuca at the top. White oval depicts the location of the Hunt Road Side Channel DIDSON site. The East Channel ARIS site is located approximately adjacent to the upper right hand portion of the white oval.



Figure 2. Photo of the HRC DIDSON site. Note low water that precluded fish passage up this channel during the majority of the coho run.



Figure 3. East Channel or Mainstem SONAR site. The SONAR is attached to the pole mount which is in turn attached to the ladder. The PVC picket weir immediately downstream from the ladder directs fish away from the bank so they pass at least 3 m from the SONAR head.

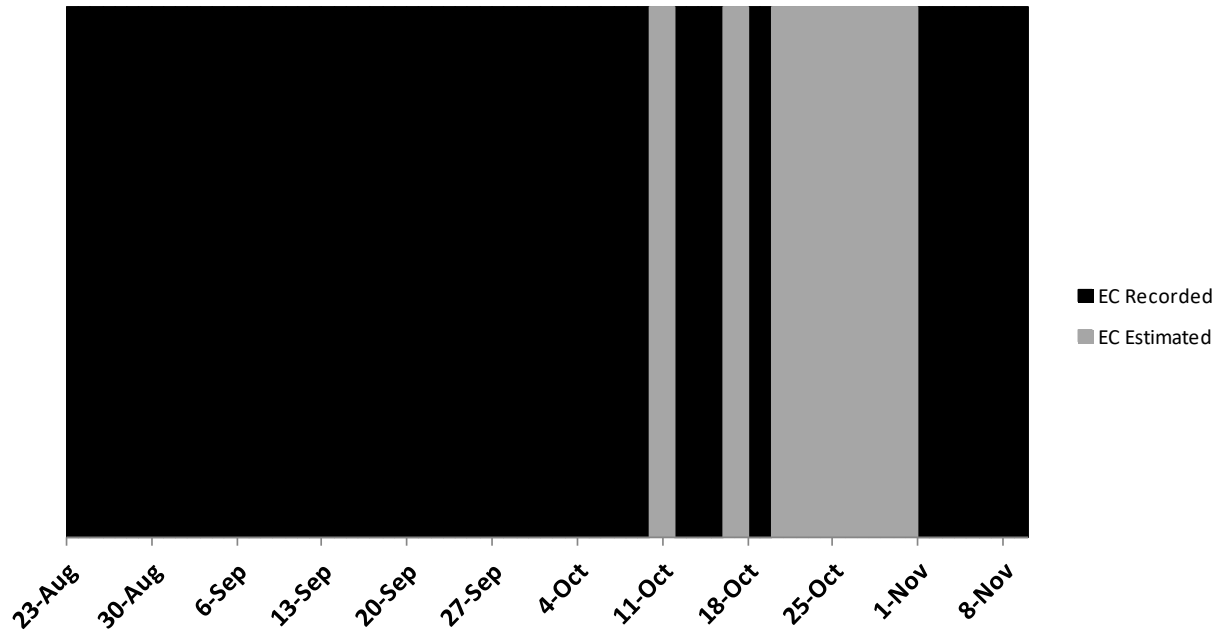


Figure 4a. Dates for which data was recorded or estimated in the East Channel during the coho season on the Elwha River in 2021.

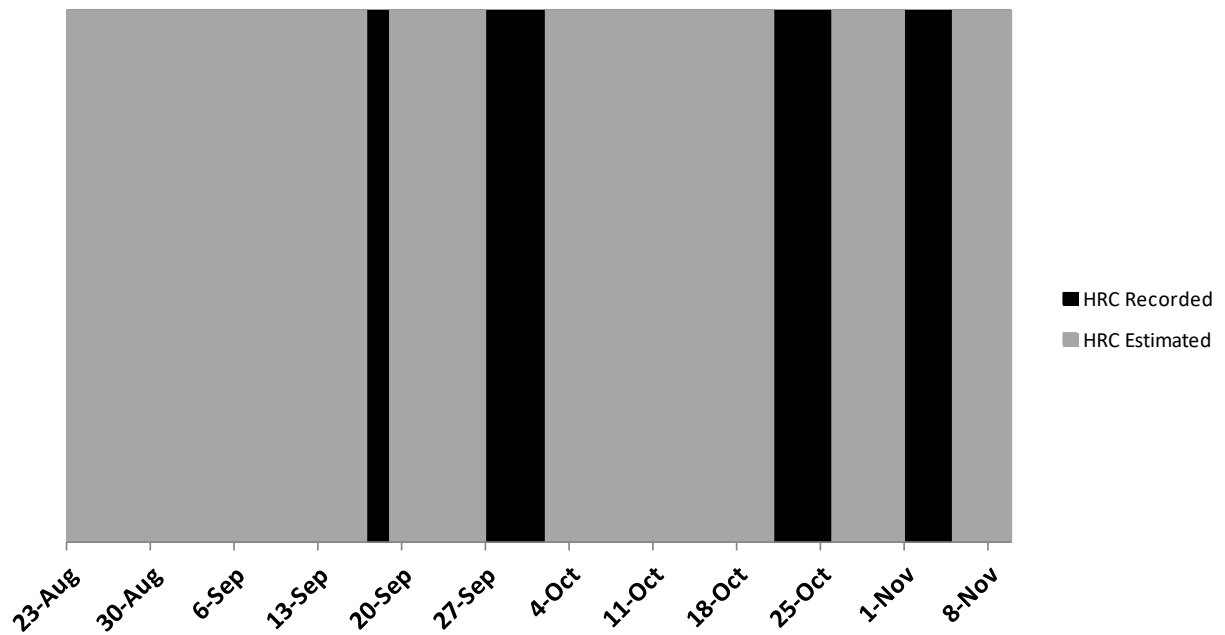


Figure 4b. Dates for which data was recorded or estimated in the Hunt Road channel during the coho season on the Elwha River in 2021.

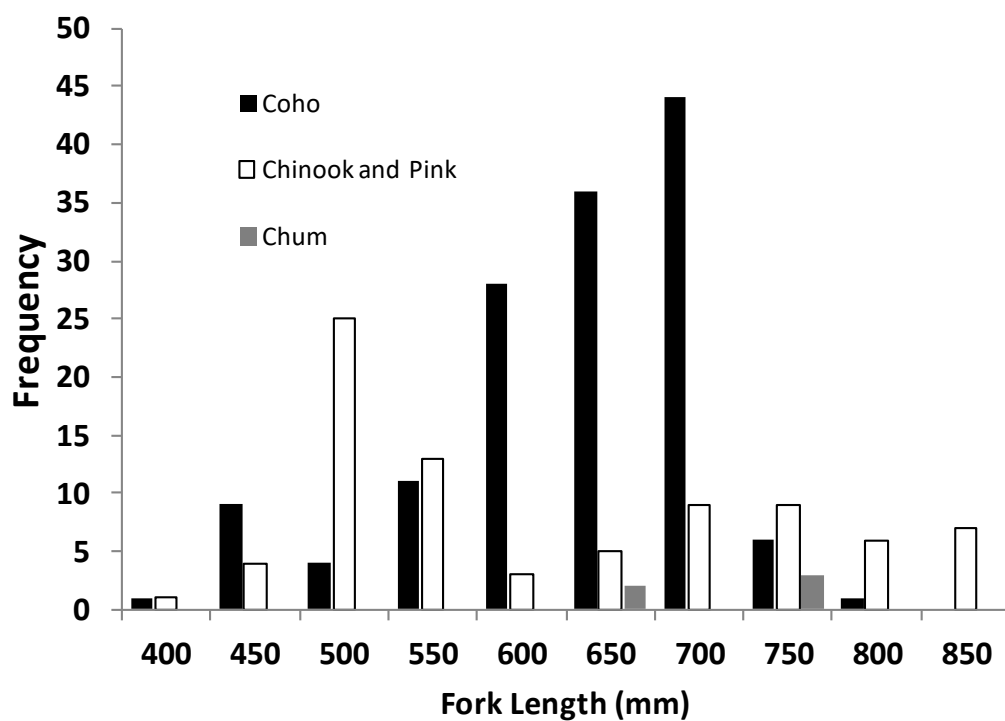


Figure 5. Length frequency histogram for all salmonids caught during 9 different sampling days between August 23, 2021 and November 2, 2021 in the Elwha River.

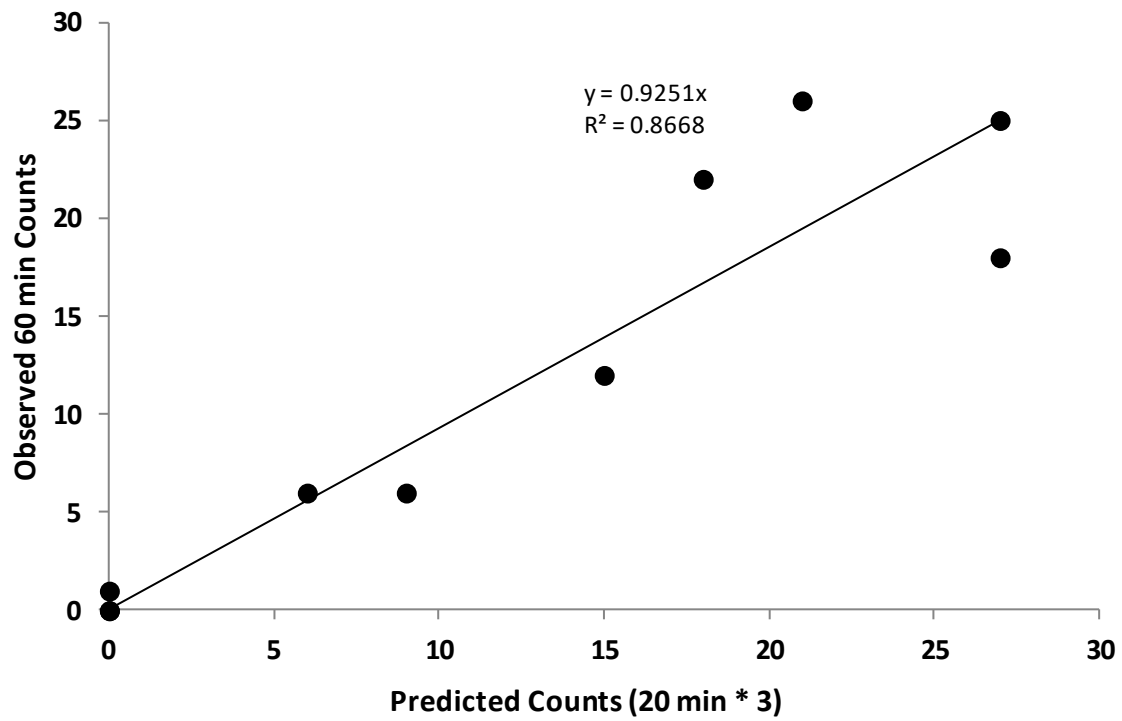


Figure 6. Predicted (20 minutes \* 3) vs. observed (actual 60 minute counts) for 10 six-hour chunks of full hour counts for the East Channel (EC). Point (0,0) has two data points.

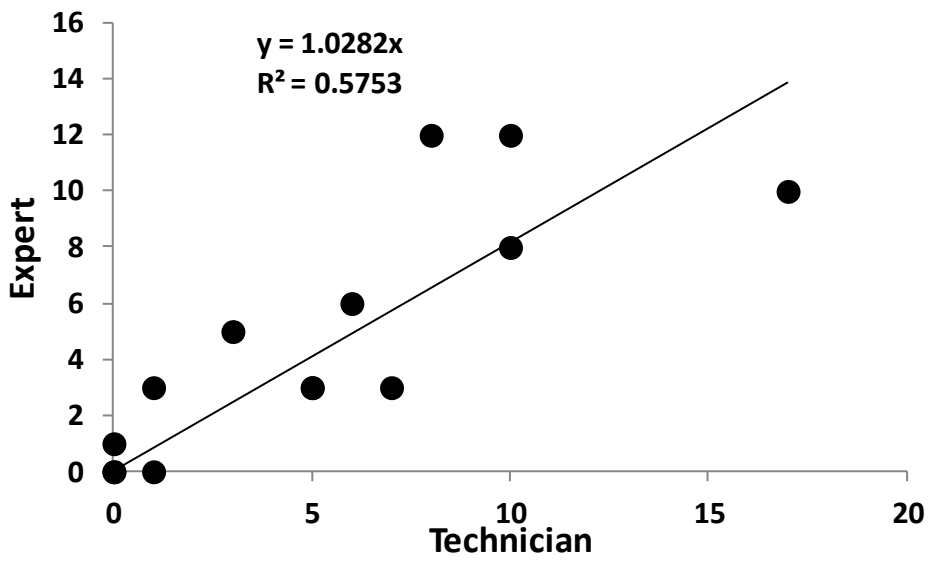


Figure 7. Total upstream passage counted by a technician and expert for 14 six-hour chunks. Point (0,0) has two data points.

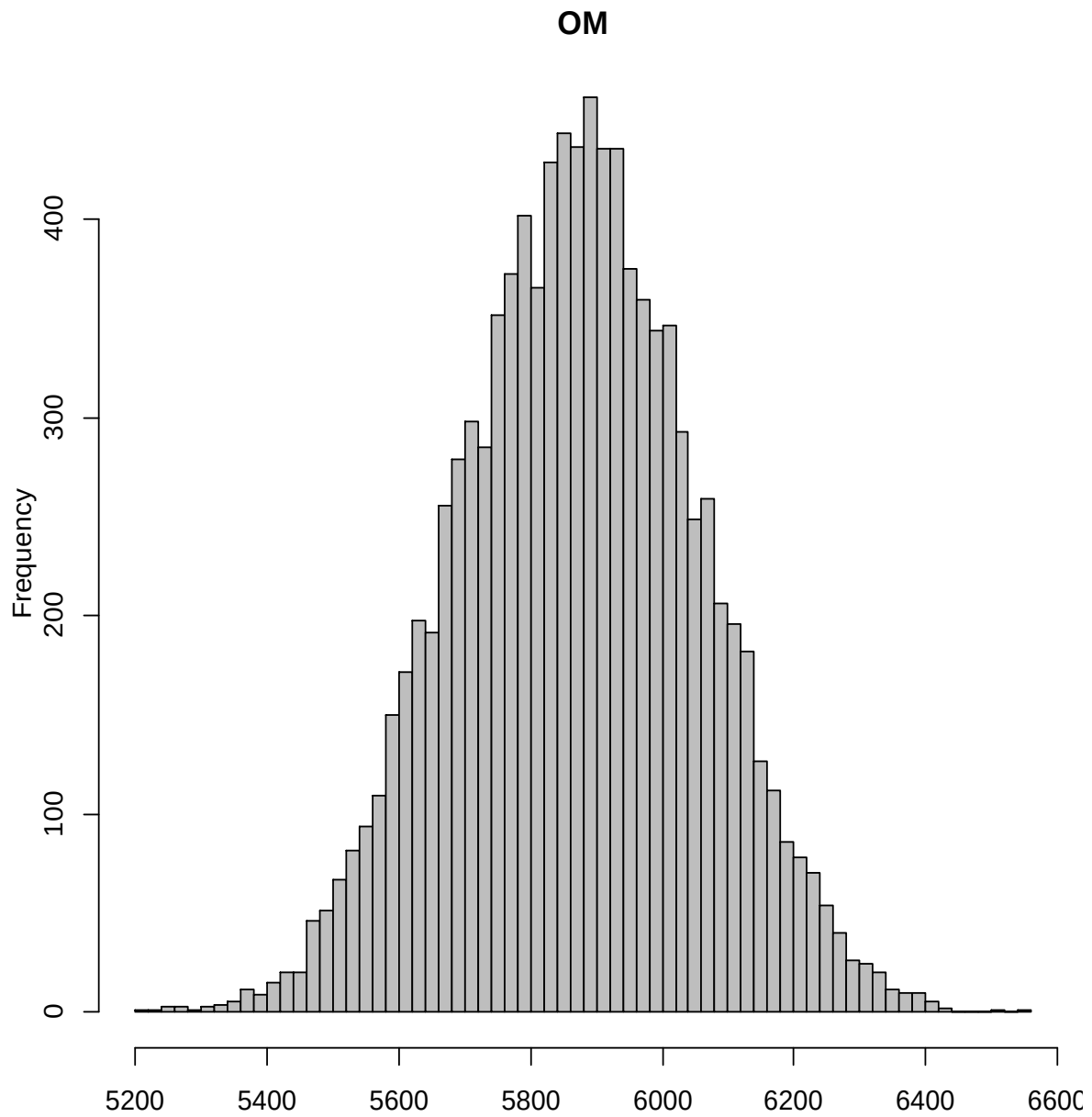


Figure 8. East Channel (EC) coho run size estimates for the Elwha River in 2021 based on 10,000 model runs. This shows only non-jack (>500 mm) coho salmon numbers.

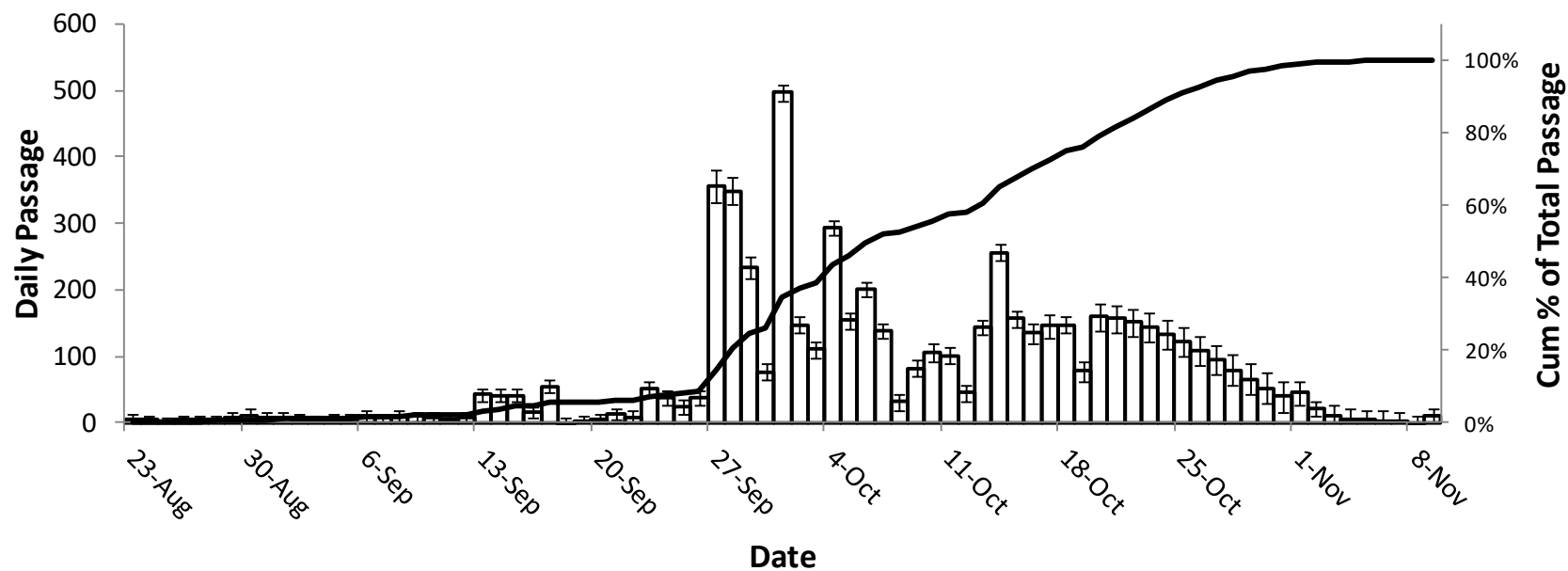


Figure 9. Daily coho passage (> 500 mm) and cumulative percent of total run for the East Channel (EC) in the Elwha River in 2021. Daily passage values have been adjusted for subsampling expansion, species composition, observer error, and data gaps. Error bars represent the standard deviation of passage for each day. Total passage estimate for the EC was 5,900 coho salmon.

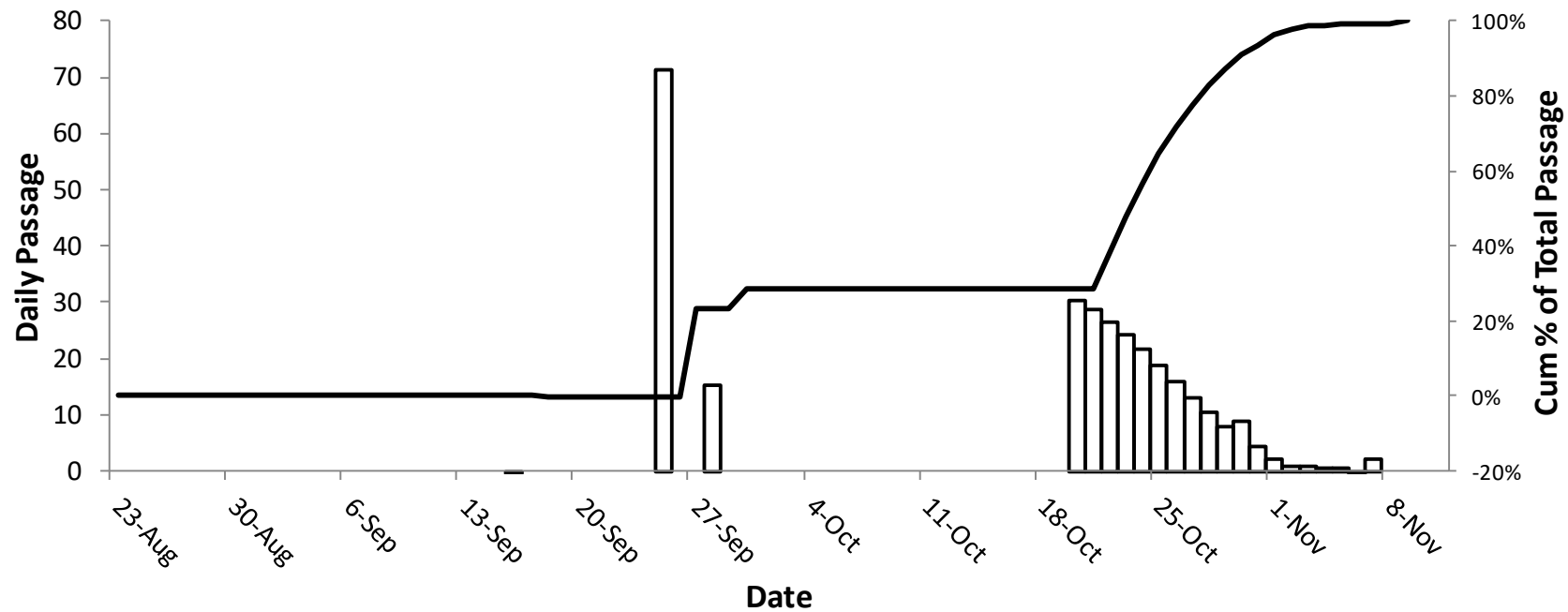


Figure 10. Daily coho passage and cumulative percent of total run for the Hunt Road Channel (HRC) in the Elwha River in 2021 as predicted by the medium estimation method. The medium passage estimate for this channel and method was 300 fish.

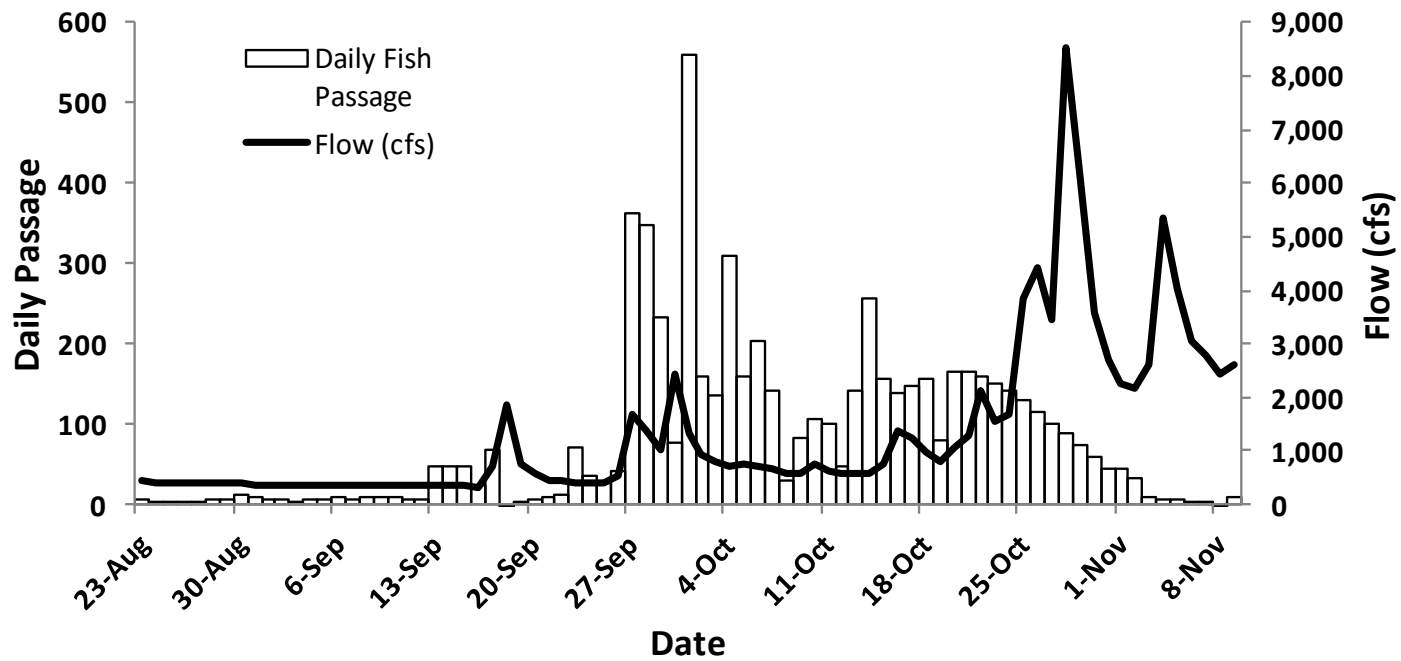


Figure 11. Daily coho passage and flow (cfs) for the Elwha River in 2021. This graph only represents passage up the EC channel.